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No Radio Bursts Detected from FIRST J141918.9+394036 in Green Bank Telescope Observations

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1. Introduction

Precise localization of the first-known repeating fast radio burst source, FRB 121102 (Spitler et al. 2016; Chatterjee et al. 2017), led to its association with a star-forming region inside a low-metallicity dwarf host galaxy (Tendulkar et al. 2017). This host environment is similar to that typically associated with long gamma-ray bursts (GRB) and superluminous supernovae, potentially linking these astrophysical phenomena (Metzger et al. 2017). In addition, the bursting source is found to be spatially coincident with a compact (< 0.7 pc; Marcote et al. 2017), persistent radio source (Chatterjee et al. 2017). Ofek (2017) identified similar radio sources in the Very Large Array FIRST survey (Becker et al. 1995). One of these sources, FIRST J141918.9+394036 (hereafter FIRST J1419+3940), was identified as a radio transient decaying in brightness by a factor of ~50 over several decades (Law et al. 2018). Very-long-baseline radio interferometric observations support the theory that FIRST J1419+3940 is the afterglow of a long GRB, based on the inferred physical size of the emission region (1.6 ± 0.3 pc; Marcote et al. 2019).

FIRST J1419+3940 and FRB 121102's persistent radio sources have similar properties and host galaxy type. Although FIRST J1419+3940 is declining in brightness, its peak luminosity ($\nu L_\nu > 3 \times 10^{38}$ erg s^{-1} at 1.4 GHz; Law et al. 2018) is comparable to the mean luminosity of FRB 121102's persistent radio source ($\nu L_\nu \approx 3 \times 10^{38}$ erg s^{-1} at 1.7 GHz; Chatterjee et al. 2017). Possibly, their physical nature could be similar, and FIRST J1419+3940 could contain a source capable of producing millisecond-duration radio bursts. Above ~1.4 GHz, FIRST J1419+3940 is observed to have an optically thin synchrotron spectrum (Law et al. 2018). This, combined with the relatively close proximity of FIRST J1419+3940 (87 Mpc, about an order-of-magnitude closer than FRB 121102; Tendulkar et al. 2017; Law et al. 2018), indicates that it should be possible to detect much lower energy bursts than those observed from FRB 121102, if FIRST J1419+3940 is producing FRBs. Marcote et al. (2019) reported the non-detection of bursts from FIRST J1419+3940 during 4.3 hr of observations with the 100 m Effelsberg telescope at 1.7 GHz. Here, we report the non-detection of bursts from FIRST J1419+3940 using the 110 m Green Bank Telescope (GBT).

2. Observations and Analysis

Table 1 summarizes the observations. We observed FIRST J1419+3940 for a total duration of 3.1 hr using the GBT and the Breakthrough Listen backend (MacMahon et al. 2018) on MJDs 58519 and 58529—at both *S*-band (1.73–2.6 GHz) and *C*-band (3.95–8.0 GHz). The time and frequency resolutions were 349.5 μs and 0.366 MHz, respectively. In addition to the target scans, both noise diode and test pulsar (PSR B1508+55) scans were taken.

Table 1. Summary of Observations and Fluence Upper Limits

Scan Start Time[a]	Frequency Range	Duration	$T_{sys} + T_{bg}$[b]	Gain	Fluence Limit[c]
(MJD)	(GHz)	(min)	(K)	(K/Jy)	(Jy ms)
58519.4457	3.95–8.0	30.0	28	1.85	0.05
58519.4667	3.95–8.0	30.0	28	1.85	0.05
58519.5059	1.73–2.6	6.7	25	1.9	0.1
58529.1809	3.95–8.0	30.0	28	1.85	0.05
58529.2019	3.95–8.0	30.0	28	1.85	0.05
58529.2305	1.73–2.6	30.0	25	1.9	0.1
58529.2514	1.73–2.6	28.0	25	1.9	0.1

Notes.

[a]Topocentric. [b]System temperature (T_{sys}) are for typical GBT performance: http://www.gb.nrao.edu/~fghigo/gbtdoc/perform.html. Background temperature (T_{bg}) is a combination of the sky temperature (negligible in this case, using the 408 MHz all-sky map (Remazeilles et al. 2015) and extrapolating to our observing frequencies using a spectral index of −2.7 (Reich & Reich 1988)) and the cosmic microwave background ~3 K (Mather et al. 1994). [c]Calculated following Cordes & McLaughlin (2003), assuming a 1 ms wide burst with DM = 300 pc cm^{-3}, using the temperature and gain values listed, with a signal-to-noise detection threshold of 10.

We searched for bursts using `PRESTO`[8] (Ransom 2001). We identified and masked radio frequency interference (RFI) using `PRESTO`'s `rfifind` and dedispersed using `prepdata` to create timeseries with trial dispersion measures (DM) of 0–1000 pc cm^{-3}. As is discussed in Marcote et al. (2019), the expected DM toward FIRST J1419+3940 is <170 pc cm^{-3}, ignoring any contribution from the host galaxy. If we assume the host contribution is comparable to that of FRB 121102, then the expected DM is ~400 pc cm^{-3}. We then searched for single pulses above a 6σ threshold in the dedispersed time series using `single_pulse_search.py`. The single pulses due to RFI were filtered using an automated classifier (Michilli & Hessels 2018). Our search was sensitive to bursts with widths between ~0.5 and 34.95 ms. The identified candidates were all deemed to be non-astrophysical after inspecting their dynamic spectra by eye. This analysis strategy was verified by performing a blind search for the test pulsar PSR B1508+55.

3. Results and Discussion

In this search, we were sensitive to 1 ms wide bursts from FIRST J1419+3940 exceeding the fluence limits shown in Table 1, assuming DM ~300 pc cm^{-3}. Considering the weakest bursts observed from FRB 121102 (0.02 Jy ms; Gajjar et al. 2018) and scaling to the luminosity distance of FIRST J1419+3940 (87 Mpc; Law et al. 2018), we find the corresponding fluence to be 2.5 Jy ms, well exceeding our detection threshold. We found no astrophysical bursts in these observations. If we assume there is a source associated with FIRST J1419+3940 that is producing FRBs, the lack of detection could indicate a quiescent state, as is often observed for FRB 121102 (e.g., Gajjar et al. 2018). Alternatively, the bursts could be beamed away from our line-of-sight. It is also possible that FIRST J1419+3940 does not contain a source capable of producing FRBs. Future searches are important to constrain the possible presence of an FRB-emitting source.

Footnotes

8 https://github.com/scottransom/presto

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